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RESEARCH ARTICLE

Violet Laser Acupuncture—Part 4: Acute Effects on Human Arterial Stiffness and Wave Reflection

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Abstract
We investigated the effects of violet laser acupuncture on arterial stiffness and other important parameters of the functional state of the heart such as augmentation index (AIx). This investigation ties together the medical perspectives of Eastern and Western medical practitioners; the Western medical perspective of the functional states of the human heart including systolic and diastolic blood pressures, and the Eastern medical perspective regarding taking patients' pulses for diagnosis and using acupuncture for subsequent treatments. Pulse wave velocity (PWV) is a direct marker of arterial stiffness; AIx indicates wave reflection. Both parameters can be measured by cuff applied to the brachial artery. The first results from a pilot study of 10 healthy volunteers (M/F, 3/7; mean age ± SD, 27.8 ± 6.8 years) regarding violet laser acupuncture (405 nm; 110 mW; 500 μm; 10 min) showed a marked but not statistically significant decrease in aortic PWV and an increase in brachial AIx during and after laser acupuncture at the acupoint Baihui. Further studies including control measurements are necessary.

1. Introduction

Palpating the pulse is one of the oldest medical procedures. Even today, some Asians refer to going to the doctor as "going to have my pulse felt" [1]. This response shows the high esteem in which pulse diagnosis is held within Eastern medicine. In Western medicine, computer-based pulse wave analysis allows diagnosis and prognosis concerning the functional state of the arteries and the heart.

New biomedical technologies involving noninvasive methods providing sensitive and compact electronic devices are revolutionizing many medical fields. The development and first applications of new oscillometric methods for assessment of human arterial stiffness might,

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for example, be described as being in an adolescent stage, where their power and potential can be recognized but are still developing rapidly.

Pulse wave velocity (PWV) is widely recognized as a direct marker of arterial stiffness. The augmentation index (AIx) is being used more often in studies as a parameter of wave reflection [2].

Violet laser acupuncture has been described for the first time recently by our research group [3–8]. In the first three parts of the study reproducible effects on brain circulation (multidirectional transcranial ultrasound Doppler sonography), peripheral microcirculation (laser Doppler flowmetry), and temperature distribution (thermal infrared imaging) were presented in the *Journal of Acupuncture and Meridian Studies* [3–5].

The goal of this fourth part of the series was to review the current literature on this topic and to perform pilot investigations on possible acute effects of violet laser acupuncture on arterial stiffness and wave reflection in 10 healthy volunteers using a new noninvasive method.

2. Materials and Methods

2.1. Data acquisition and signal analysis of hemodynamic function

The methods for determining arterial stiffness and wave reflection parameters were noninvasive; measurements were performed with a cuff applied to the brachial artery (Fig. 1).

The new, noninvasive system Arteriograph™ (TensioMed, Budapest, Hungary) uses an entirely novel method to determine PWV and AIx (Fig. 2). Signals can be detected from an upper arm cuff, even if it is overinflated by 35–40 mmHg beyond the systolic blood pressure, despite a completely closed brachial artery [2].

The parameters listed in Table 1 were calculated.

2.2. Violet laser acupuncture

Laser needle acupuncture has been described in detail in the first three parts of the study [3–5] and in previous works [6–11]. A research system from Laserneedle EG GmbH (Wehrden, Germany) as mentioned in parts 1–3 of the study [3–5] was used for the measurements (wavelength, 405 nm; output power, 110 mW; laser needle spot diameter, 500 μm; time, 10 min). The system consists of 10 semiconductor injection laser diodes. Each single needle can emit a different wavelength. In the present study a continuous wave (CW) mode was used. Because of coupling losses, the output at the tip of the laser needle is about 100 mW. Irradiation lasted 10 min (600 s); therefore optical power energy density was very high (in kJ/cm^2 range) [3–5,9,10].

2.3. Volunteers, acupuncture, and procedures

Within the first pilot study, the noninvasive parameters of human arterial stiffness and wave reflection of 10 healthy volunteers (M/F, 3/7) with a mean age ± standard deviation (SD) 27.8 ± 6.8 years were investigated during violet laser acupuncture. The measurement profile and measurement times (a–c) are shown schematically before, during, and after violet laser stimulation in Fig. 3.

None of the volunteers was taking any medication. All volunteers were informed about the nature of the investigation as far as the study design allowed. The study was

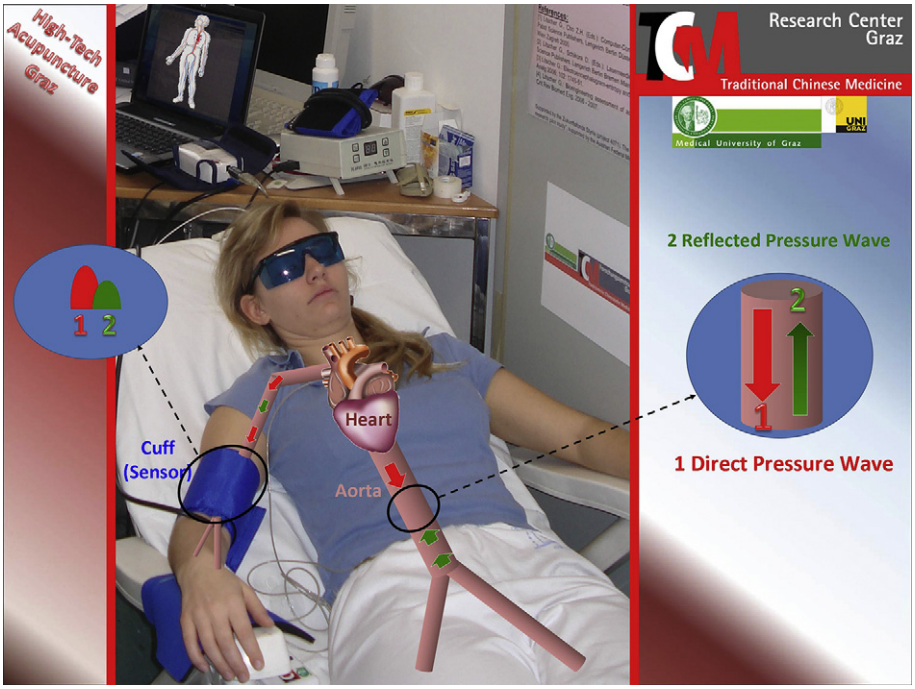

Figure 1 Measurement of PWV and AIx using a cuff at the brachial artery in the lab of the TCM Research Center Graz at the Medical University of Graz.

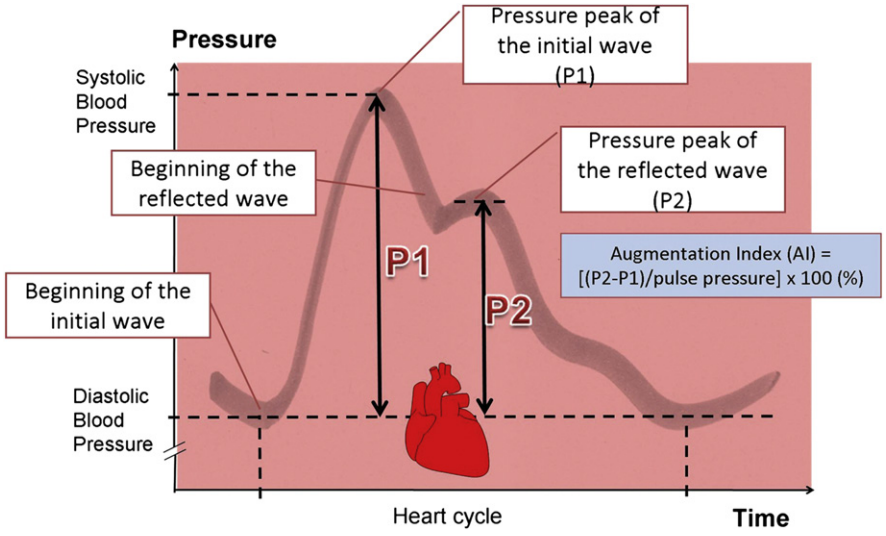

Figure 2 Parameters for noninvasive assessment for the estimation of human arterial stiffness and wave reflection.

approved by the local ethics committee, and all volunteers gave their written informed consent.

The volunteers lay on a bed in our lab (Fig. 1). Room temperature was kept constant at 25°C. Three measurement periods before (a), during (b), and after (c) violet laser stimulation were compared (Fig. 3).

Acupuncture stimulation was performed at the acupoint Baihui (GV20), which is one of the most important acupoints

Table 1 Parameters calculated by noninvasive system Arteriograph™

Abbreviation	Unit	Parameter	Description
AIx brachial	%	Brachial augmentation index	Describes influence of reflected pulse wave on systolic pressure (in percent pulse pressure). AIx is closely linked to functional disturbances of the vasculature.
AIx aortic	%	Aortic augmentation index	Aortic augmentation (see also AIx brachial).
PWVao	m/s	Aortic pulse wave velocity	Describes the stiffness of the aortic vascular wall; considered a direct measure of (aortic) arterial stiffness, giving decisive clinically important prognostic information.
SDPWVao	m/s	Standard deviation of PWV	Describes the variance of the PWVao-values during the suprasystolic recording phase. If values exceed 1.1 m/s, the measurement needs to be repeated very carefully. High to very high SDPWVao values will be found in cases of atrial fibrillation (physiologic), but can also be caused by arm movements (and the pressure variations they cause) during the recording phase.
PP	mmHg	Pulse pressure or blood pressure amplitude	Difference of systolic and diastolic blood pressure values expressed in mmHg. PP values >60 are considered independent risk factors, especially if diastolic pressure is normal or low. Increased values are an indirect indicator of increased arterial stiffness.
PPao	mmHg	Aortic pulse pressure or blood pressure amplitude	Superior prognostically compared with conventional, peripheral PP measured at the upper arm.
SBPao	mmHg	Central systolic blood pressure, close to the aortic root	Values are those "seen" by the heart (afterload); they represent stress to which coronary and cerebral arteries are exposed; thus are closely correlated to circulatory disorders and prognosis.
ED	ms	Ejection duration of left ventricle	Time between opening and closing of the aortic valve.
RT	ms	Reflection time	Time the pulse wave needs from the aortic root to the bifurcation and back. The stiffer the aortic walls, the shorter reflection time.
Sys (BPsys)	mmHg	Systolic blood pressure	"Conventional" brachial blood pressure.
Dia (BPdia)	mmHg	Diastolic blood pressure	"Conventional" brachial blood pressure.
MAP	mmHg	Mean arterial blood pressure	Calculated from systolic and diastolic blood pressure values.
HR	BPM (1/min)	Heart rate	Heart rate.

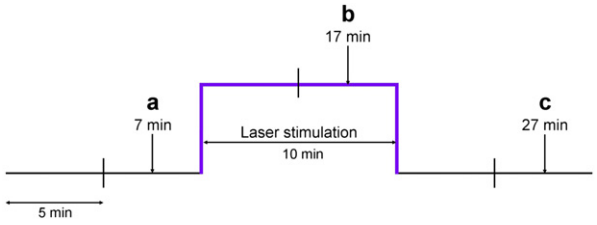

Figure 3 Measurement profile.

of the Du meridian (governing vessel) and commonly used in neurology and psychiatry [12]. The location of Baihui is on the continuation of the line connecting the lowest and highest points of the ear, on the median line of the head, 7 cun above the posterior hairline and 5 cun behind the anterior hairline [13].

2.4. Statistical analysis

Data were analyzed by one-way repeated measures ANOVA (SigmaPlot 11.0; Systat Software Inc., Chicago, IL, USA). The level of significance was defined as $p < 0.05$.

3. Results

Fig. 4 summarizes the preliminary results of the parameter AIx of the 10 participants. AIx values increased during the laser acupuncture; however, statistical significance was not reached.

The velocity of the pulse wave between the aortic root and the bifurcation of the aorta in m/s is displayed in Fig. 5.

Stimulation with violet laser at Baihui also resulted in insignificant changes in standard monitoring parameters such as heart rate and mean arterial blood pressure (Fig. 6).

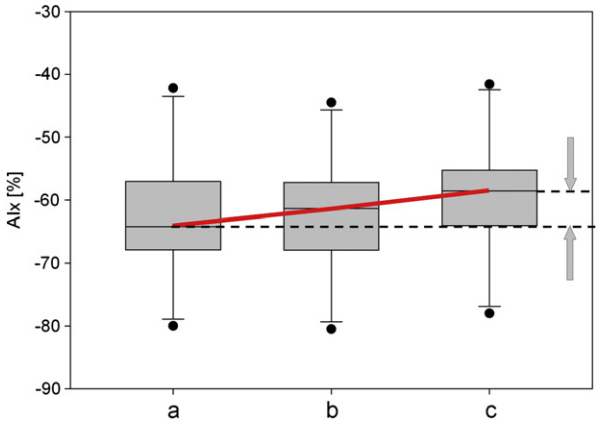

Figure 4 Brachial augmentation index (AIx) in %, which describes the influence of the reflected pulse wave on systolic pressure (in percent of pulse pressure), of the 10 healthy volunteers before (a), during (b), and after (c) violet laser acupuncture. The ends of the boxes define the 25th and 75th percentiles, with a line at the median and error bars defining the 10th and 90th percentiles.

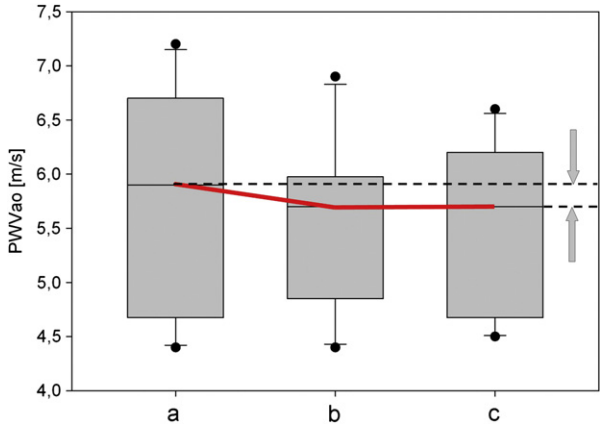

Figure 5 PWVao (aortic pulse wave velocity in m/s) of the 10 healthy volunteers before (a), during (b), and after (c) violet laser acupuncture. For further explanation of the box plot see Fig. 4.

4. Discussion

Even before biomedicine and biomedical engineering began spreading across the globe from their origins in Western Europe, interest in acupuncture, an ancient traditional Chinese treatment method, was growing outside Asia. Each culture that has absorbed acupuncture has influenced its development. However, reliable evidence on the measurable effects of acupuncture (needle, laser, electro acupuncture) has only been reported within the last several years [14–24].

The present study includes a new application of the new oscillometric era in measuring arterial stiffness in the field of acupuncture. As of February 2011, only five scientific articles concerning "arterial stiffness and acupuncture," "wave reflection and acupuncture," and "pulse wave velocity and acupuncture" could be found in the scientific database PubMed (www.pubmed.gov). A summary of the current scientific literature on the topics arterial stiffness, wave reflection, and acupuncture is listed in Table 2; publications by scientists from China, Japan, Mexico, and Taiwan can be found in this listing [25–29].

PWV and AIx increase in somewhat different ways, in parallel to the aging process, and convey different information regarding the arterial vascular status [30,31]. Both parameters provide extensive information on the arterial vascular system, and the prognostic significance of arterial stiffness should be very high [2].

The first results from our pilot study in ten healthy volunteers regarding violet laser acupuncture and acute effects on human arterial stiffness and wave reflection showed minor, nonsignificant increase in brachial AIx and a decrease in the aortic PWV. No other parameters showed significant or even minor changes.

There were some limitations in this pilot study. There was a small number of subjects ($n = 10$) and also no control group with deactivated laser. Therefore, based on the results of this pilot study and of the previous studies listed in Table 2, we plan to conduct a larger study further to investigate these preliminary findings. Our hypothesis is that acupuncture (manual needle or violet laser

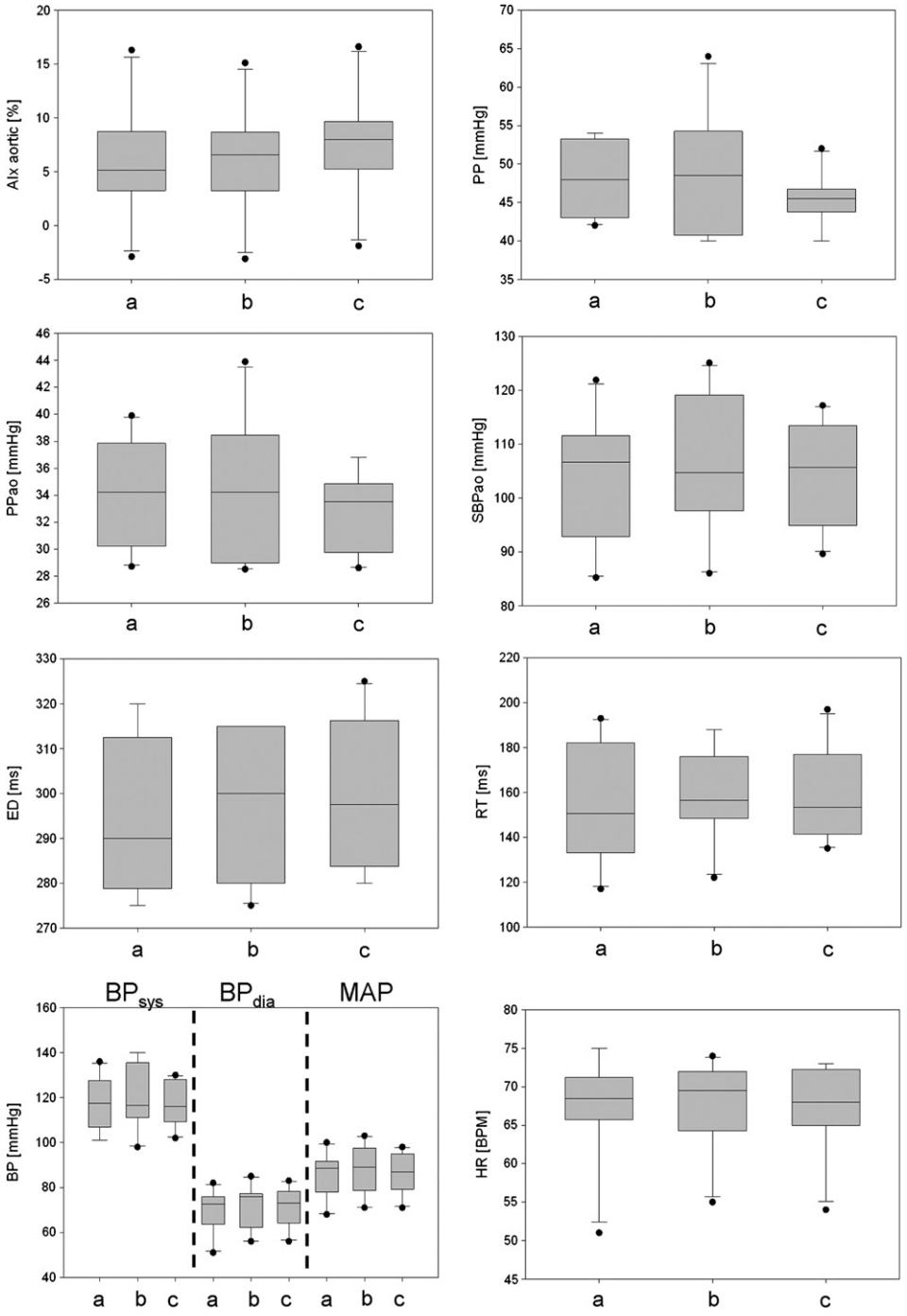

Figure 6 From top to bottom and from left to right: Central augmentation index (AIx aortic), brachial pulse pressure (PP), aortic pulse pressure (PPao), central systolic blood pressure (SBPao), ejection duration of left ventricle (ED), return time (RT), systolic blood pressure (BPsys), diastolic blood pressure (BPdia), and mean arterial pressure (MAP) of the 10 healthy volunteers before (a), during (b), and after (c) violet laser acupuncture. For further explanation of the box plots, see Fig. 4.

stimulation) can influence the autonomic nervous system. We want to show that these stimulation methods cause measurable, reproducible physiological alterations, especially in the parameters of human arterial stiffness and wave reflection. These responses have only been shown in one study [25] using needle acupuncture but could not be demonstrated clearly (i.e., there were nonsignificant changes) in our pilot investigation. Further investigations are necessary. With reference to the present study, the difference between laser and needle acupuncture on the parameters mentioned above is also a future matter of research.

Traditional Chinese medicine in general and acupuncture in particular have been used for medical treatment for thousands of years. A large number of empirical data are available, but the technical quantification of effects was

Table 2 Summary of research on human arterial stiffness and wave reflection during acupuncture

Author(s)	Year	Method	n	Investigations in	Findings	Acupuncture
Satoh [25]	2009	Arterial stiffness, wave reflection, augmentation index	25	Male volunteers	AI radial ↑ BPdia ↑	Manual needle (Baihui; GV20)
Rivas-Vilchis et al. [26]	2008	Digital volume pulse	70	40 nonsmokers 30 smokers	SDDVP index ↑	Manual needle (Neiguan; PC6)
Rivas-Vilchis et al. [27]	2007	Digital volume pulse	65	40 healthy subjects 25 untreated hypertensive subjects	SDDVP index ↑	Manual needle (Neiguan; PC6)
Tan et al. [28]	2006	F-wave	56	Patients after cervical operations (acupuncture + massage, n = 30; acupuncture + medication, n = 26)	Amplitude ↓	Manual needle (traditional points)
Lin et al. [29]	2003	Finger blood flow	14	Healthy volunteers	FBF ↓ BP ↓ PVT ↑	Electro (Hegu; LI4)

AIx brachial, augmentation index from the brachial artery; PWVao, aortic pulse wave velocity; AI radial, augmentation index from radial artery; BPdia, diastolic blood pressure; SDDVP index, index of second derivative of digital volume pulse; FBF, finger blood flow; BP, arterial blood pressure; PVT, paravertebral temperature.

not possible. Using needle or optical stimulation (laser acupuncture) and modern biomedical techniques, changes in vital parameters can now be quantified noninvasively.

5. Conclusions

PWV between the aortic root and the bifurcation of the aorta decreased markedly (yet insignificantly), whereas the AIx increased during and after violet laser acupuncture at the acupoint Baihui. More substantial data are required in the future.

Acknowledgments

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References

1. Yuan HP. *Chinesische Pulsdiagnostik*. München: Urban & Fischer; 2009.
2. Baulmann J, Schillings U, Rickert S, Uen S, Düsing R, Illyes M, et al. A new oscillometric method for assessment of arterial stiffness: comparison with tonometric and piezo-electric methods. *J Hypertens*. 2008;26:523—528.
3. Litscher G, Huang T, Wang L, Zhang WB. Violet laser acupuncture—part 1: effects on brain circulation. *J Acupunct Meridian Stud*. 2010;3:255—259.
4. Wang L, Huang T, Zhang WB, Litscher G. Violet laser acupuncture—part 2: effects on peripheral microcirculation. *J Acupunct Meridian Stud*. 2010;4:24—28.
5. Litscher G, Wang L, Huang T, Zhang WB. Violet laser acupuncture—part 3: effects on temperature distribution. *J Acupunct Meridian Stud*. 2011;4:164—167.
6. Litscher G. Modernization of traditional acupuncture using multimodal computer-based high-tech methods—recent results of blue laser and teleacupuncture from the Medical University of Graz. *J Acupunct Meridian Stud*. 2009;2:202—209.
7. Litscher G, Xie Z, Wang L, Gaischek I. Blue 405 nm laser light mediates heart rate—investigations at the acupoint Neiguan (Pe.6) in Chinese adults. *North Am J Med Sci*. 2009;1:226—231.
8. Litscher G, Wang L, Xie Z, Gaischek I. Blauer Laser in der Akupunktur—ein erster Review-Report. *Schweiz Z Ganzheitsmed*. 2010;22:167—170 [in German].
9. Litscher G, Schikora D, editors. *Laserneedle-acupuncture. Science and practice. Lengerich: Pabst Science Publishers; 2005*.
10. Litscher G. High-tech laser acupuncture is Chinese medicine. *Med Acupunct*. 2008;20:245—254.
11. Litscher G. Asian-Austrian high-tech acupuncture research network. Transcontinental and translational high-tech acupuncture research using computer-based heart rate and 'fire of life' heart rate variability analysis. *J Acupunct Meridian Stud*. 2010;3:156—164.
12. Shen EY, Chen FJ, Chen YY, Lin MF. Locating the acupoint Baihui (GV20) beneath the cerebral cortex with MRI reconstructed 3D neuroimages. *Evid Based Complement Alternat Med*. 2010. doi:10.1093/ecam/neq047.
13. Stux G, Pomeranz B. *Basics of Acupuncture*. Berlin: Springer; 1998.
14. Litscher G. Bioengineering assessment of acupuncture, part 1: thermography. *Crit Rev Biomed Eng*. 2006;34:1—22.
15. Litscher G. Bioengineering assessment of acupuncture, part 2: monitoring of microcirculation. *Crit Rev Biomed Eng*. 2006;34:273—294.
16. Litscher G. Bioengineering assessment of acupuncture, part 3: ultrasound. *Crit Rev Biomed Eng*. 2006;34:295—326.
17. Litscher G. Bioengineering assessment of acupuncture, part 4: functional magnetic resonance imaging. *Crit Rev Biomed Eng*. 2006;34:327—345.

18. Litscher G. Bioengineering assessment of acupuncture, part 5: cerebral near infrared spectroscopy. *Crit Rev Biomed Eng*. 2006;34:439—457.
19. Litscher G. Bioengineering assessment of acupuncture, part 6: monitoring neurophysiology. *Crit Rev Biomed Eng*. 2007;35: 1—38.
20. Litscher G. Bioengineering assessment of acupuncture, part 7: heart rate variability. *Crit Rev Biomed Eng*. 2007;35:183—195.
21. Litscher G. Bioengineering assessment of acupuncture, part 8: innovative moxibustion. *Crit Rev Biomed Eng*. 2010;38:117—126.
22. Litscher G. Ten years evidence-based high-tech acupuncture—a short review of centrally measured effects (part II). *Evid Based Complement Alternat Med*. 2009;6:305—314.
23. Litscher G. Ten years evidence-based high-tech acupuncture—a short review of peripherally measured effects. *Evid Based Complement Alternat Med*. 2009;6:153—158.
24. Litscher G. Ten years evidence based high-tech acupuncture—a short review of animal experiments. *Evid Based Complement Alternat Med*. 2008. doi:10.1093/ecam/nen034. published online May 7.
25. Satoh H. Acute effects of acupuncture treatment with Baihui (GV20) on human arterial stiffness and wave reflection. *J Acupunct Meridian Stud*. 2009;2:130—134.
26. Rivas-Vilchis JF, Escorcia-Gaona R, Cervantes-Reyes JA, Román-Ramos R. Vascular responses to manual PC6 acupuncture in nonsmokers and smokers assessed by the second derivative of the finger photoplethysmogram waveform. *J Acupunct Meridian Stud*. 2008;1:58—62.
27. Rivas-Vilchis JF, Hernández-Sánchez F, González-Camarena R, Suárez-Rodriguez LD, Escorcia-Gaona R, Cervantes-Reyes JA, et al. Assessment of the vascular effects of PC6 (Neiguan) using the second derivative of the finger photoplethysmogram in healthy and hypertensive subjects. *Am J Chin Med*. 2007;35: 427—436.
28. Tan T, Wang SC, Zhang GJ. Effect of acupuncture and massage at tendon on F-wave of electromyogram in the patient of flexor spasm of the upper limb after operation of cervical spondylosis. *Zhongguo Zhen Jiu*. 2006;26:725—728.
29. Lin CF, Liao JM, Tsai SJ, Chiang PY, Ting H, Tang CY, et al. Depressor effect on blood pressure and flow elicited by electroacupuncture in normal subjects. *Auton Neurosci*. 2003;107: 60—64.
30. McEniery CM, Yasmin, Hall IR, Qasem A, Wilkinson IB, Cockcroft JR. ACCT Investigators. Normal vascular aging: differential effects on wave reflection and aortic pulse wave velocity: the Anglo-Cardiff Collaborative Trial (ACCT). *J Am Coll Cardiol*. 2005;46:1753—1760.
31. Baulmann J, Homsi R, Uen S, Düsing R, Fimmers R, Vetter H, et al. Pulse wave velocity is increased in patients with transient myocardial ischemia. *J Hypertens*. 2006;24:2085—2090.